

APPARATUS AND METHODS FOR ABRADING A WORK PIECE

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 60/450,242, filed February 25, 2003.

FIELD OF THE INVENTION

[0002] The present invention generally relates to the abrading of work pieces, and more particularly relates to abrading of work pieces using an abrading apparatus having an upper abrading wheel support system and an integrated fluid delivery system.

BACKGROUND OF THE INVENTION

[0003] It has long been known to use precision abrading processes to bring work piece surfaces to a desired state of refinement or dimensional tolerances. This is done commonly by using a process known as abrading, which removes small, controlled amounts of material from the work piece. Typical abrading machines comprise upper and lower abrading wheels with abrasive surfaces that are disposed parallel and opposite to each other. The work pieces to be abraded are positioned upon the lower abrading wheel and the upper abrading wheel is lowered so that the working surface of the upper abrading wheel may contact the work piece and rotate to abrade the work piece.

[0004] Currently available abrading machines have proven undesirable in several respects. Many abrading machines today employ a single column design that utilizes a single column to which a support arm is mounted. A pneumatic or hydraulic cylinder coupled to the support arm effects vertical reciprocation of the upper abrading wheel relative to the lower abrading wheel. However, the single column design has a tendency to generate a cantilever moment during the abrading process. That is, when pressure is exerted during the abrading cycle, the support arm and column tend to act as a cantilever with torque about the end of the single column. This cantilever effect results in loss of rigidity and control of the position of the upper abrading wheel. Hence, sizing accuracy is reduced.

[0005] Moreover, many available abrading machines have proven unsatisfactory due to oscillation of the upper abrading wheel during the abrading process. Typically, the upper abrading wheel is attached to the pneumatic or hydraulic cylinder using swivel bearings or other similar components. However, during rotation, the upper abrading wheel tends to oscillate in a substantially horizontal plane. This oscillating motion also results in a loss of rigidity and control of the upper abrading wheel and, hence, reduces sizing accuracy.

[0006] Many available abrading machines also employ an unsatisfactory coolant delivery system. Coolant delivery systems are used to deliver a coolant to the working surfaces of the abrading wheels to remove debris and particulates from the working surfaces and the work pieces and to reduce the temperature of the abrading process. Typically, it is desirable to deliver the coolant to the working surfaces under pressure to facilitate debris and residue removal. One type of coolant delivery system utilizes a tube or conduit that extends from a coolant supply reservoir to the working surface of the lower abrading wheel. However, this configuration results in an uneven distribution of coolant and, hence, a non-uniform cooling of the working surfaces and inadequate removal of debris and residue.

[0007] Another type of coolant delivery system utilizes a ring-like trough disposed above the upper abrading wheel and connected to conduits that extend to the working surface of the upper abrading wheel. A nozzle arrangement delivers a coolant from a coolant reservoir to the trough. However, as the upper abrading wheel rotates at high speeds, the coolant splashes out of the trough. Consequently, less coolant is delivered to the working surfaces of the abrading wheels, thus adversely affecting cooling of the abrading process and the efficiency of the residue and debris removal. In addition, such splashing of the coolant may result in coolant depositing on components of the abrading machine. The undesirable coolant deposits may adversely affect the functionality of the machine and may require downtime to remove the coolant deposits and clean the machine.

[0008] Accordingly, it is desirable to provide an abrading apparatus having an upper abrading wheel support system that provides rigidity and control of the upper abrading wheel, thus enhancing sizing accuracy. In addition, it is desirable to provide an abrading apparatus with an improved integrated coolant delivery system. Furthermore, other desirable features and characteristics of the present invention will become apparent from the subsequent detailed description of the invention and the appended claims, taken in conjunction with the accompanying drawings and this background of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and

[0010] FIG. 1 is a perspective view of an abrading apparatus in accordance with an exemplary embodiment of the present invention;

[0011] FIG. 2 is a schematic side cross-sectional view of the abrading apparatus of FIG. 1; and

[0012] FIG. 3 is a cross sectional view of a rotary coupler in accordance with an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] The following detailed description of the invention is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any theory presented in the preceding background of the invention or the following detailed description of the invention.

[0014] Referring to FIGS. 1 and 2, an abrading apparatus 10 for abrading any suitable work piece 30, or a number of work pieces 30, comprised of metal, ceramic, wood, stone, semiconductor material, such as silicon, or any other abradable material is illustrated. As used herein, the term “abrading” is used in accordance with its ordinary dictionary definition, and comprises grinding, polishing, planarizing, finishing, honing, and lapping. In accordance with one exemplary embodiment of the present invention, abrading apparatus 10 comprises a base 12 within which is at least partially disposed a lower abrading wheel assembly employing a lower abrading wheel 14. Lower abrading wheel 14 may have any abrading surface 16 suitable for abrading a particular work piece. The lower abrading wheel assembly also employs a motor 80, which serves to move lower abrading wheel 14 in a rotational, linear, orbital, or oscillatory manner, or a combination thereof. In a preferred embodiment of the invention, motor 80 rotates lower abrading wheel 14 about a central axis.

[0015] Two support members 18 are fixedly attached at first ends 20 to base 12 and extend vertically from base 12 to form a frame structure of apparatus 10. The two support members 18 may be disposed a suitable distance from each other in an imaginary vertical plane 90 to effect stable and rigid support of an upper wheel assembly, described in more detail below. The two support members 18 may be attached to base 12 by any suitable fastening device or method, such as screws, bolts, adhesive, welding, and the like. The two

support members 18 may be coupled proximate to second ends 22 by a bridge or brace 24 to reduce or eliminate the tendency for the support members 18 to rotate about their ends 20. The two support members 18 may be formed of any suitable rigid material and structure, such as, for example, round, square, or triangular, metal or polymer pipes or tubes.

[0016] Apparatus 10 further comprises a carriage member 26 that extends, at least partially, from approximately the two support members 18 in a direction substantially perpendicular to plane 90. In one exemplary embodiment of the invention, carriage member 26 has at least two flanges 32, each of which is connected to one of two linear ball bearing slide assemblies 28. Each of the linear ball bearing slide assemblies 28 is mounted to a support member 18 for vertical movement of carriage member 26 along support members 18. It will be understood that, while carriage 26 is illustrated in FIGS. 1 and 2 connected to linear ball bearing slide assemblies 28 via flanges 32, the invention is not so limited and carriage 26 may be connected to linear ball bearing slide assemblies 28 using any suitable mechanism and/or device.

[0017] At least one vertical drive device 34 is mounted to carriage member 26 to move carriage member 26 in a reciprocal vertical manner. In a preferred embodiment of the invention, apparatus 10 comprises two vertical drive devices, each disposed proximate to one of the support members 18, although it will be appreciated that any suitable number of vertical drive devices 34 may be connected to carriage member 26 and configured to move carriage member vertically. The vertical drive devices 34 may be fixed at their lower ends to suitable structure of apparatus 10, such as, for example, base 12, for support. Vertical drive devices 34 may comprise any device suitable for raising and lowering carriage member 26, such as, for example, pneumatic cylinders and hydraulic cylinders. In a preferred embodiment of the invention, as illustrated in FIG. 2, vertical drive devices 34 may comprise air/oil cylinders that facilitate the smooth vertical motion of carriage member 26. Examples of air/oil cylinders suitable for use in apparatus 10 include air/oil cylinders manufactured by TRD Manufacturing, Inc. of Loves Park, Illinois. In one exemplary embodiment of the invention, the air/oil cylinders each may comprise at their upper ends a piston 36 slidably disposed within a cylinder 38, which may be connected to an air/oil tank 40. To raise piston 36, and thus carriage 26 to which piston 36 is coupled, a gas 42, such as air, may be pumped into air/oil tank 40, which in turn forces hydraulic oil 44 in oil tank 40 through a conduit 46 and an open solenoid on/off valve 86 into cylinder 38 under piston 36. As the oil level in cylinder 38 rises, piston 36 is moved vertically upward through cylinder 38. The solenoid valve 86 then may be closed to prevent back flow of the oil. To lower

piston 36, and thus carriage 26, the solenoid valve 86 may be opened and the gas 42 in air/oil tank 40 may be released, causing the oil in cylinder 38 to flow back through conduit 42 into air/oil tank 40. As the oil level in cylinder 38 falls, piston 36 is moved vertically downward within cylinder 38.

[0018] Referring again to FIGS. 1 and 2, a spindle 48 is mounted to and is supported by carriage member 26. As described in more detail below, spindle 48 is disposed a distance from plane 90 and, thus, support members 18. Spindle 48 is connected at a first end to a rotary drive mechanism 50 that is configured to rotate spindle 48 about a longitudinal axis 52. Rotary drive mechanism 50 may comprise any suitable devices and/or systems that are configured to rotate spindle 48 about longitudinal axis 52. In one embodiment of the invention, spindle 48 may be attached to a first pulley 54, which is coupled to a second pulley 56 by a belt 58. Second pulley 56 is connected to a motor 60, which, when in operation, rotates second pulley 56 about its central axis. Motor 60 may be suitably disposed anywhere within carriage member 26. In one preferred embodiment of the invention, motor 60 is disposed, at least partially, between two support members 18. As second pulley 56 rotates, it drives belt 58, which in turn rotates first pulley 54 about its central axis. As first pulley 54 rotates about its central axis, it causes spindle 48 to rotate about longitudinal axis 52. While rotary drive mechanism 50 is illustrated in FIGS. 1 and 2 utilizing a belt and pulley assembly, it will be understood that rotary drive mechanism 50 may comprise any other suitable mechanism for rotating spindle 48. For example, in another alternative embodiment of the present invention, rotary drive mechanism 50 may comprise a gear assembly formed of mutually engaged gears that may be rotated by activation of motor 60.

[0019] Spindle 48 comprises a hollow channel 66 that is disposed parallel to and coaxial with the longitudinal axis 52 of spindle 48. A first opening 68 of channel 66 is disposed proximate to at least one conduit (not shown) of a rotary lead-through member 64. Rotary lead-through member 64 is mounted to spindle 48 and may comprise a rotary bearings assembly or any other suitable assembly that permits spindle 48 to rotate about its longitudinal axis 52 relative to rotary lead-through member 64, which remains stationary, while permitting fluid to flow through the conduit of the rotary lead-through member 64 into hollow channel 66. An example of a rotary lead-through member 64 suitable for use in apparatus 10 comprises the One-Pass 90 Degree Swivel (300 Series) manufactured by Rotary Systems, Inc. of Anoka, Minnesota. Rotary lead-through member 64 in turn is coupled to a supply line 62, which is connected to a fluid source (not shown) and,

optionally, a fluid pump (not shown). In this regard, fluid may be provided to supply line 62 from the fluid source under pressure. The pressurized fluid may then flow through the conduit of rotary lead-through member 64 and into channel 66 of spindle 48.

[0020] Spindle 48 is mounted at a second end to an upper abrading wheel assembly 70. Upper abrading wheel assembly 70 comprises an upper abrading wheel support 72 and an upper abrading wheel 88 having a working surface 74. In one embodiment of the invention, abrading wheel assembly 70 is mounted to spindle 48 such that spindle 48 and upper abrading wheel 88 are coaxial. Working surface 74 of upper abrading wheel 88 is disposed parallel to and opposes working surface 16 of lower abrading wheel 14. As described above, spindle 48, and hence upper abrading wheel assembly 70, are disposed a distance from plane 90 of the two support members 18. In this regard, upper abrading wheel assembly 70 is readily accessible for cleaning, replacing of parts, assembly adjustments, and the like. Similarly, because lower abrading wheel 14 is vertically opposed to upper abrading wheel working surface 74, lower abrading wheel 14 is also disposed a distance from plane 90 and, thus, is more accessible for the loading and unloading of work pieces and for maintenance. Moreover, because upper abrading wheel assembly 70 is disposed outside of plane 90 and not within plane 90, the distance between the two support members 18 may be minimized while still minimizing the cantilevering of support members 18 and carriage member 26. Thus, the size of apparatus 10 may be minimized without compromising the rigidity of apparatus 10. In a preferred embodiment of the invention, spindle 48 and upper abrading wheel assembly 70 are disposed equal distances relative to the x-axis and y-axis from each of the two support members 18.

[0021] To provide rigid rotation of upper abrading wheel 88 and to minimize any undesirable oscillation of upper abrading wheel 88 during an abrading operation, upper abrading wheel assembly 70 comprises a rotary coupler 76 that couples upper abrading wheel 88 to spindle 48. As described in more detail below, rotary coupler 76 comprises a plurality of first conduits (not shown). Each first conduit is disposed at a first end proximate to a second opening 78 of longitudinal channel 66 of spindle 48. Each first conduit is coupled at a second end to a second conduit 82, such as a tube or pipe, that extends from rotational coupler 76 to upper abrading wheel support 72. Upper abrading wheel support 72 and upper abrading wheel 88 in turn comprise a number of channels 84, which may be randomly disposed within upper abrading wheel support 72 and upper abrading wheel 88 or may be disposed in accordance with a desired pattern. A first opening of each channel 84 is

connected to one tube 82. The second opening of each channel 84 is disposed at working surface 74 of upper abrading wheel 72.

[0022] FIG. 3 is an enlarged view of an exemplary embodiment of rotary coupler 76. Rotary coupler 76 comprises a driver hub 300 that may be attached to spindle 48 and that has an aperture 312 that is coaxial with longitudinal channel 66 of spindle 48. Driver hub 300 may be attached to spindle 48 using a first series of bolts 302 that are located circumferentially about driver hub 300. Alternatively, any other suitable fastening device or method, such as for example, screws, clamps, adhesives, weldings, and the like, may be used to mount driver hub 300 to spindle 48. In one exemplary embodiment of the invention, driver hub 300 also comprises fins 304 that engage recesses disposed on spindle 48. In this regard, as spindle 48 rotates about longitudinal axis 52, driver hub 300 also rigidly rotates about longitudinal axis 52.

[0023] Rotary coupler 76 further comprises a universal joint 306 that is mounted to driver hub 300. Universal joint 306 may be mounted to driver hub 300 by a second series of bolts 308 that are located circumferentially about universal joint 306, or by any other suitable fastening device or method, as described above. One or more O-rings 310 may be disposed between driver hub 300 and universal joint 306 to enhance the frictional forces between driver hub 300 and universal joint 306 and to facilitate the sealing of universal joint 306 to driver hub 300.

[0024] Disposed proximate to a bottom end of driver hub 300 is a number of conduits 314. Conduits 314 may be disposed completely within driver hub 300, or may be formed by open cavities that are machined into driver hub 300 and are closed to form conduits when universal joint 306 is attached to driver hub 300. Each conduit 314 is disposed at a first end 316 proximate to the aperture 312 of driver hub 300 and is coupled at a second end 318 to a tube 82 that extends from a passageway 328 of universal joint 306 to upper abrading wheel support 72. In this regard, a fluid, such as a coolant or a drying gas, may be urged through longitudinal channel 66 of spindle 48 and may flow through aperture 312 of driver hub 300 into the plurality of conduits 314. The fluid then may pass through conduits 314 of driver hub 300 and passageways 328 of universal joint 306 into tubes 82. From tubes 82, the fluid may travel through upper abrading wheel support 72 to the working surface 74 of upper abrading wheel 88 and to the work piece.

[0025] To couple the upper abrading wheel support 72 to universal joint 306, rotary coupler 76 also comprises a housing 320, which may be mounted to universal joint 306 by a third series of bolts 322 disposed circumferentially about a bottom surface of universal joint

306. Alternatively, housing 320 may be mounted to universal joint 306 by any other suitable fastening device or method, as described above. The union of universal joint 306 and housing 320 may be sealed from fluid leaks by sealing members 324. Sealing members 324 may comprise any suitable sealing device or method, such as, for example, polymer sealing rings, silicon sealant, and the like. Housing 320 in turn is mounted to upper abrading wheel support 72 by a fourth series of bolts 326 circumferentially disposed about housing 320.

[0026] A method for abrading a work piece using an exemplary embodiment of apparatus 10 will now be described with reference to FIGS. 1-3. The method may begin with carriage member 26 at a loading and unloading position. One or more work pieces 30 to be ground, polished, planarized, or otherwise finished may be positioned suitably on working surface 16 of lower abrading wheel 14. Vertical drive device 34 then may be actuated to vertically lower carriage member 26 from the loading/unloading position to a working position. The travel distance between these two positions may be such that cantilevering of the support members 18 and carriage member 26 may be minimized and the overall rigidity of apparatus 10 may be increased. Carriage member 26 may slide downward along slide assemblies 28 until working surface 74 of upper abrading wheel 88 contacts the work piece 30. Motor 80 then may be activated to rotate lower abrading wheel 14 about a central axis. Similarly, motor 60 may be activated to cause second pulley 56 to rotate. As second pulley 56 rotates, friction between second pulley 56 and belt 58 drives belt 58 to rotate about rotary device mechanism 50. As belt 58 rotates, friction between belt 58 and first pulley 54 causes first pulley 54 to rotate about its central axis. The rotation of first pulley 54 causes spindle 48 to rotate about its longitudinal axis 52, which in turn causes rotary coupler 76, upper abrading wheel support 72, and upper abrading wheel 88 to rotate about their central axis.

[0027] During or upon lowering of carriage member 26 to the working position, a coolant may be supplied under pressure to supply line 62. While the coolant may be supplied at any suitable pressure, in one exemplary embodiment of the invention, the coolant may be supplied at a flow rate in the range of about 0.5 gal./min. to about 3 gal./min. In a more preferred embodiment of the invention, the coolant may be supplied at a flow rate in the range of about 1 gal./min to about 2 gal./min. The coolant may flow from supply line 62 through the conduit of rotary lead-through member 64 and into the first opening 68 of longitudinal channel 66 of spindle 48. The coolant may pass through longitudinal channel 66 and exit the second opening 78 of longitudinal channel 66 into the aperture 312 of driver hub 300 and into the conduits 314 of driver hub 300. The coolant then is urged through the

conduits 314 into tubes 82 and to the working surface 74 of upper abrading wheel 88 via channels 84. In this regard, a pressurized coolant may be delivered to working surface 74 of upper abrading wheel 88 to facilitate removal of debris and residue from the work pieces and lower the temperature of the work pieces and working surfaces, thus enhancing the abrading process.

[0028] In one exemplary embodiment of the invention, once the abrading process is completed, the vertical drive device 34 may be activated to raise carriage member 26 so that working surface 74 of upper abrading wheel 88 is not contacting the work piece. Carriage member 26 may be raised to the loading/unloading position or may be raised to a position a distance below the loading/unloading position. The flow of coolant through supply tube 62 then may be terminated and a pressurized gas, such as, for example, compressed air, may be delivered to supply line 62. The pressurized gas may travel the same path as the coolant for delivery through channels 84 of upper abrading wheel support 72 and upper abrading wheel 88 to the work piece 30. In this manner, the pressurized gas may be used to blow coolant and any remaining residue from the work piece and prevent stiction of the work piece to working surface 74 of upper abrading wheel 88.

[0029] Before the abrading process, and/or any optional drying process, are completed, or, alternatively, upon completion of the abrading process and/or any optional drying process, motors 60 and 80 may be de-activated to terminate the rotation of rotary drive mechanism 50 and lower abrading wheel 14. Vertical drive device 34 then may be activated to raise carriage member 26 to the loading/unloading position so that the work piece 30 may be removed from lower abrading wheel 14.

[0030] Accordingly, there is provided an apparatus for performing abrading operations, such as grinding, polishing, lapping, honing, and the like. The apparatus comprises an upper abrading wheel and a lower abrading wheel, each with working surfaces disposed parallel and opposite to each other and each coupled to a motor for rotating the wheels. The apparatus utilizes an upper abrading wheel support system that rigidly supports the upper abrading wheel during an abrading process. The apparatus also employs a novel integrated coolant delivery system that provides for the uniform and contained delivery of coolant to the working surfaces.

[0031] While at least one exemplary embodiment has been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or

configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment of the invention. It being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.